PNEUMATIC
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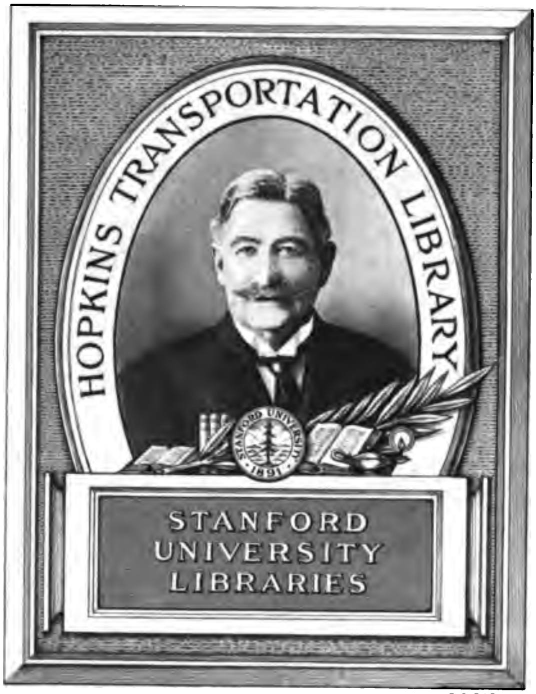
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tion of the process. The position of the parties is, indeed, very clearly explained at the commencement thus:—

"Art. 1. A partnership will be established between MM. Niepce and Daguerre for the purpose of working out the said discovery invented by M. Niepce, and improved by M. Daguerre."

We all know how Niepce died a few years after this agreement was made, while the world was yet unacquainted with the works he had so patiently and modestly accomplished, and how Daguerre in 1839 communicated to the Paris Academy the wonderful process of Daguerreotype, a method which, while dissimilar and superior to that of Niepce, was nevertheless due in some measure to that philosopher's discoveries. All honour and fame to Daguerre for making one mighty stride of progress in the beautiful art of photography, but we should doubtless have admired him more if, when publishing his invention to the world, instead of ignoring Niepce's early aid, he had generously made some mention of the labours of his dead partner.

II. PNEUMATIC TRANSMISSION.

By Frederic Charles Danvers, A.I.C.E.

THE practical application of air to the transmission of carriages on land dates only from the commencement of the present century. The first idea, however, of transmitting power to a distance by means of pneumatic pressure appears to have originated with the celebrated Denys Papin, a Frenchman, who, in 1688, described an apparatus in which a partial vacuum produced in a long tube, by air pumps fixed at one end, caused the motion of pistons at the other end; but no record remains to prove that any steps were taken by Papin to carry his suggestions into effect so as to derive any useful practical advantage from them. The introduction of the locomotive engine naturally directed the attention of engineers and others to the subject of the provision of improved means of communication, and this desire was doubtless stimulated by the acknowledged defects of the locomotive at that time, and its reputed inapplicability for lines with gradients exceeding 1 in 100. The first person to introduce the atmospheric system of propulsion was a mechanical engineer named George Medhurst, who, in 1810, published a pamphlet on the subject entitled "A New Method of Conveying Letters and Goods with

Great Certainty and Rapidity by Air," in which may be recognised the first practical suggestions for the introduction of what is now known as the "Pneumatic System;" and it is not a little surprising to find that in this, and two subsequent pamphlets by the same author, are foreshadowed almost everything that has hitherto been discovered in connection with this subject—all subsequent inventions having reference merely to the detailed means for carrying that system into effect.

George Medhurst's first idea clearly was to employ the pneumatic system for the conveyance of small parcels only, but he subsequently suggested its application for the transport of goods of a more bulky nature. It is perhaps a pity that he did not confine his attention in the first instance to the development of his earliest ideas on the subject, and which has subsequently been proved to be the most practical method of applying his inventions, viz., for the transmission of letters and small parcels. The rage of the day being, however, for improved means of communication, it is not surprising that his own ambition and the popular clamour should have caused Medhurst to endeavour to apply his invention to a purpose for which it was ill-suited. We shall not now follow the progress of the gradual rise and fall of the atmospheric railway, from the time when John Vallance, in the year 1826, constructed a model tunnel in Devonshire Place, Brighton, 120 feet long, and nearly 8 feet in diameter, through which a carriage was propelled by means of air pumps worked by two steam engines, which was the first of its kind ever constructed, to the abandonment of the atmospheric principle upon the Paris and St. Germains line for the last mile and a-half of its length, which was taken up in the year 1860, after having been in successful operation for about 15 years. From this last-named circumstance it is clear that the atmospheric system is not wholly unsuited for railways under certain circumstances, the chief ground of its applicability being upon very steep inclines, such as were unsuited for locomotives. The inconvenience, however, of having different systems of propulsion upon the same railway has been the cause which has led to the abandonment of the atmospheric principle upon every railway where it has ever been tried; the general advantages, greater speed, and undoubted superiority of the locomotive gaining for it, in every case, the preference over the latter.

Thus ended all attempts to introduce atmospheric railways; but a few years before their final abandonment the adaptation of the principle for the transmission of small

parcels was again revived, and it now seems likely to come into very general use, especially in connection with the Post Office and the Telegraphs. The want of some means of speedy communication between the offices of the Electric and International Telegraph Company in London, in addition to that afforded by their lines of wire, probably led to the invention of a pneumatic tube for that purpose by Mr. Latimer Clark, and the first tube was laid down by that company in 1855. This tube was of lead, and the carrier (in which messages were placed) nearly fitted the bore, and was covered with felt. It turned out to be a complete success, and a similar principle was adopted by the Prussian Telegraph Administration in Berlin, between the Telegraph Office and Exchange, in the year 1863; in 1866 it was also adopted in Paris in connection with the Electric Telegraph stations in that city. Later still the principle has been introduced into New York, and quite recently a line has been laid down by Messrs. Siemens, in connection with the General Post Office in London, for the conveyance of messages in original between Telegraph Street and Charing Cross and on to the House of Commons, instead of sending them by Telegraph.

There are two methods which have at different times been adopted for impelling carriers through pneumatic tubes, the one being by creating a vacuum in front of the carrier, which is then impelled forward by the atmospheric pressure with a force equal to the difference between the latter and the vacuum. The other is by creating a "plenum" behind the carrier, or, in other words, increasing the pressure behind the carrier beyond that of the atmosphere, the difference between these two forces in pounds or ounces per square inch representing the force expended in driving the carrier through the tube. Medhurst, in his first invention, adopted the latter principle, and the introduction of the vacuum for the purpose is ascribed to John Vallance, who proposed it in a pamphlet published by him in 1824. Experience has shown that the vacuum is the far preferable manner of working pneumatic tubes, and it is also more economical than working with a plenum.

The difference between the effects of compression and exhaustion would appear, so far as recorded experiments upon the subject show, to vary in the cases of tubes of different diameters; but as a general rule it has been observed that when a carrier is inserted into a tube it is driven forwards with a mean velocity corresponding to that with which the air at the higher pressure is introduced behind it, or that at the lower pressure is exhausted in front of it. In a paper read

before the British Association at Liverpool last year by Mr. Robert Sabine, that gentleman has worked out a number of formulæ for calculating the work performed in pneumatic tubes, and the result of his investigations on this subject cannot fail to be of great value, as it is one upon which very little of scientific value has hitherto been published. "The problem of a successful pneumatic system," says Sabine, "is simply this: To make a given quantity of air expand from one pressure to another in such a way as to return a fair equivalent of the work expended in compressing it. It is obviously impossible to regain the full equivalent of the work, because the compression is attended with the liberation of heat, which is dissipated and practically lost to us. Therefore, in designing a pneumatic system, that which we have to do is first to contrive means of compressing the air as economically as possible; secondly, to get back as much as we can of the mechanical effect stored up in our already compressed air, irrespectively of the work which was employed in compressing it. The utmost theoretical work which a given quantity of air can be made to perform is evidently that of expanding from the higher to lower pressure; and the mechanical effect employed in propelling a carrier and air through a given tube is therefore equivalent to that due to the expansion of a tubeful of air from the higher to the lower pressure." The speed at which a carrier travels in a horizontal tube has been worked out by Sabine, and is expressed by the following equation:—

$$s=\sqrt{2g\frac{vf-Wl\mu}{W+\frac{w_1+w_2}{2}v\left(1+\zeta\frac{l}{d}\right)}}\text{ feet per second.}$$

But when going up or down an incline—

$$s=\sqrt{2g\frac{vf-Wl(\sin\alpha+\mu\cos\alpha)}{W+\frac{w_1+w_2}{2}v\left(1+\zeta\frac{l}{d}\right)}}\text{ feet per second.}$$

In these equations the volume of the tube in cubic feet is represented by v; l represents the length of the tube in feet, and d its diameter, also in feet; W is the weight of the carrier in pounds, and g the accelerated motion due to gravity; f represents the mechanical effect performed by one cubic foot of air; μ, the coefficient of friction of motion of the carrier in the tube; w_1 the weight in pounds of one cubic foot of air at the higher pressure; w_2 the weight of a cubic foot at the lower pressure, and α the angle made by the tube with the horizon, and which is + when the carrier ascends, but − when it descends. ζ is an empirical constant;

experiments to determine its value have been made by Girard, D'Aubuisson, Buff, Pecqueur, and others, who give a mean value for it of 0·02.

Dr. P. Brix, Professor at the Bau-Akademie, has published in the German "Telegraph Journal" particulars of experiments made by him upon velocity with a tube 2½ inches in diameter, laid down some years ago, by Messrs. Siemens at Berlin, between the Exchange and Central Telegraph Station, the results of which were that when working with compression the tension of the air at either end of the tube was 19·31 lbs. and 14·75 lbs., and with exhaustion, 14·75 lbs. and 10·19 lbs., respectively; the mechanical effect produced by one cubic foot of air in each case was 512·17 lbs. in the former, and 520·44 lbs. in the latter; and the weight of the air at the two extreme tensions was, in compression, 0·1099 and 0·0753 foot-pounds, and in exhaustion 0·0752 and 0·0447 foot-pounds. For each case the frictional resistance of the carriers in the tube averaged 0·1 lb.; the length, 2920 feet for each half of the tube; its diameter, 0·193 feet; and its volume, 85·49 cubic feet. With these values, the formula worked out by Sabine gives the calculated speeds in these two experiments as follows:—With compression, 34·1 feet, and with exhaustion 43·2 feet per second, or that the carrier should have occupied in the transit from station to station, in the former case 86 seconds, and in the latter 68 seconds, differing from the observations made by Dr. Brix 9 seconds in the one case, and only 2 seconds in the other. This difference, Sabine thinks, may possibly be due to an error of observation of the pressure, or possibly to the fact that the constant ζ may not be the same for small welded iron tubes as for a large cast-iron tunnel.

Mr. Sabine has also made some experiments with the tube of the Pneumatic Company, between Euston Station and High Holborn, which was some years ago designed by, and carried out under the engineering superintendence of, Mr. Rammell and Mr. Latimer Clark. This tube is ◠-shaped, 4½ feet broad and 4 feet high. The trains used were each made up of three trucks, and these were loaded with an average weight of 6 tons, making, with the carriages, a gross load of 9 tons. The average time occupied in running through the tube from Euston Station to Holborn was 7½ minutes, with a partial vacuum of 5 ozs. per square inch, whilst the empty trucks were returned to Euston Station with a compression of 5 ozs. per square inch in 6½ minutes. Assuming the temperature of the air to have been 20° C., and its mean pressure 14·75 lbs., it is calculated that in drawing

the loads through to Holborn the air was exhausted to 14·44 lbs., and in sending back the empty carriers it was compressed to 15·06 lbs. per square inch. From these data the mechanical effect due to the expansion of one cubic foot of air in the two experiments has been deduced to have been 31·964 foot-pounds with exhaustion, and 31·945 foot-pounds with compression.

In employing the same amount of mechanical effect, and the air remaining of the same mean specific gravity, Sabine finds "that the mean speed of transmission varies inversely with the length, and inversely also with the square root of the diameter of the tube. Thus, with an equal mechanical effect expended upon it in each case, a very light piston would travel through a tube of one mile long with exactly twice the speed with which it would travel through a similar tube two miles long. And further, if we had two tubes, each a mile long, one having a diameter of 4 feet and the other a diameter of 1 foot, the air in the larger tube would only travel half as fast as that in the smaller one, assuming, of course, the total work performed during the transit to be in each case equal. The cause of this is simply that the greater portion of the mechanical effect which in the larger tube is used for moving the greater mass of air, is, in the smaller one, converted into speed. If the case arose, therefore, that a pneumatic transit had to be made with a stated expenditure of work, we should proceed economically by adopting a tube of small rather than one of large sectional area. With an equal utilised engine power in each case, the mean speeds of transit of air through two tubes are inversely as the cube roots of their diameters and lengths. For instance, with a utilised effect of 10-horse power, the velocity of transit in a tube eight miles long, being 20 feet per second, that attainable with the same power in a one mile length of the same tube would be 40 feet, and if we had two tubes of equal length—one eight times the diameter of the other—the speed attained in the larger tube would be only half that attained in the former. To obtain the same speed of transit of a very light piston in two tubes of equal length and different diameters, other things being equal, the utilised horse-power must be directly proportioned to the diameter, whilst to produce the same mean speed of transit of very light pistons in tubes of equal diameter but different lengths, other things being equal, the utilised horse-powers of engines may be taken as directly proportional to the lengths. Similarly, when the lengths and diameters are equal, but the mean specific gravity of air

in the two operations are different, the mean speed of a very light piston being the same in its transits through the same tube, or through two tubes of equal dimensions, the utilised engine power is directly proportionate to the mean specific gravity of the air on the two sides of the piston. It follows from this, therefore, that in working by exhaustion less engine power is required, other things being equal, than in working through the same tube by means of compression. And it would also follow that in hot weather, and when the barometer is low, the working of a pneumatic tube should be less costly in engine power than in cold weather and when the barometer is high."

"With given utilised horse-power operating upon a given line, the velocity of a very light carrier would be reciprocally proportional to the cube root of the mean specific gravity of the air moving in it. Mr. Siemens has proposed to take advantage of this fact by the employment of hydrogen gas for propulsion in letter tubes instead of atmospheric air. The specific gravity of hydrogen is 0·07; that of air being 1. The speed attainable, therefore, by the substitution of this gas would be as—

$$1 : \frac{1}{\sqrt[3]{0{\cdot}07}}, \text{ or as 1 to } 2\tfrac{1}{2}, \text{ nearly.}$$

This plan would be easily practicable with Messrs. Siemens's system of complete circuit tubes, in which the same air is pumped round without being changed. With any of the ordinary systems by which the tube is open at one end, of course only the atmospheric air could be used in practice."

A by no means unimportant matter in connection with the working of pneumatic tubes is the mechanical means employed for producing the vacuum or plenum, as the case may be. Several methods have been introduced with this object. The first system adopted by Vallance in his model at Brighton, in 1828, was to produce the vacuum by means of air pumps worked by two steam engines, and this was the plan afterwards most generally employed on the several experimental lines of pneumatic railway laid down in different parts of the United Kingdom and elsewhere. In the Prussian pneumatic dispatch tube both compression and expansion are employed. The tube itself consists of two tubes of welded iron, $2\frac{1}{2}$ inches in internal diameter, laid parallel to one another beneath the pavement. A transverse coupling connects them together at one end, whilst at the other end they terminate in two reservoirs, between which an air-pump

exhausts the air from one and compresses it into the other, thus keeping up a continual circuit of current within the tubes.

The pneumatic system in use in Paris differs from the foregoing principally in the use of water power instead of steam-engine power for working the tubes, each station being supplied with an arrangement for compressing air. Until recently the transmission of carriers between stations was effected by means of compression alone, produced by the action of water upon a chamber full of atmospheric air. This water is obtained from the River Ourcq, and is employed in the following manner:—Three wrought-iron cylindrical vessels are erected at each station, one of which is large and the other two smaller, and of the same size as one another. The larger vessel is connected by means of a pipe with the water mains of the town, and an exhaust pipe leads from the same vessel into the sewers; each of these pipes is fitted with a valve to enable the communication to be opened and closed at pleasure. From the top of this vessel a pipe leads into the first of the two smaller reservoirs, and these again are connected together by a pipe fitted with a cock, whilst the second smaller reservoir is in communication with the pneumatic transmitter. In order to obtain a supply of compressed air, the valve is closed in the tube communicating with the sewers, and that leading to the water mains is opened, allowing the supply water to rush into the larger vessel, and to displace the air which previously filled it. This displaced air is compressed into the two smaller reservoirs until the water has risen nearly up to the top of the larger vessel. A cock, in the pipe communicating between that and the smaller reservoirs, is then closed to prevent the air returning. The water is then run out of the larger vessel into the sewers, and it again becomes filled with air, which is in turn compressed into the reservoirs as before, as soon as it is required.

The Pneumatic Dispatch Company in London employ a pair of horizontal engines to drive a fan 22 feet in diameter, by means of which the air can either be exhausted from, or forced into, the tubes at pleasure.

The latest form of pneumatic tube is that recently laid down by Mr. Siemens, from the Post Office in St. Martins-le-Grand towards Westminster, and which will probably be extended, in course of time, in other directions. Several entirely new features have been introduced in the construction of this tube, which we shall describe more fully at some future time in our chronicles of engineering, when the system

has become more perfected than it is at present. One new feature which Mr. Siemens proposes to introduce is a novel kind of blower, which he has designed, to be worked direct by the steam from a boiler, without the intervention of machinery, and which will not only effect a considerable saving in the first cost of the requirements of each station, but it will also be much more economical in working and for maintenance.

The methods adopted at the different stations on any pneumatic line differ, of course, with the various methods employed for transmission, and it is in this that very great improvements have recently been introduced by Mr. Siemens. We have stated that in the Berlin pneumatic despatch system two tubes are placed parallel to each other, and connected together at one end by a transverse coupling, whilst at the other they terminate in two reservoirs, between which an air-pump exhausts the air from one and compresses it into the other, by which means a continual circuit is maintained, and provision is made for the dispatch of messages in either direction. The tube for transmitting a carrier from any station is connected with the pressure reservoir, beyond which connection it is continued at a slight incline in which are placed two cocks, at an interval equal to the length of the carrier. Beyond the second cock the tube is open at the top in the form of a trough, into which the carrier is first placed. The first cock is then opened, allowing it to pass down the tube as far as the second cock. The former is then closed again and the latter opened, whereupon the carrier descends the inclined tube until it passes the pipe communicating with the pressure reservoir, whereupon it is caught by the current of air and blown to its destination. These carriers are thin metal cylinders, nearly filling the tube, supported by four wheels, two at each end, and alternately at right angles to each other. The receptor consists of a square box placed in continuation of the tube connected with the exhaust reservoir, with which it communicates by means of a cock bored to the same diameter as the tube itself. This box is lined with brushes, through which the carrier forces its way, and its impetus is thus checked, whilst at the extreme end is an india-rubber buffer. The Exchange station, at the other end of the tube, is supplied with similar apparatus, only, of course, without the engine, pump, &c.; instead of which the tubes are connected together by a short coupling tube. In some experiments which were made to determine the relative pressures in the two reservoirs, it was found that with

equal differences of 9 inches of mercury above and below atmospheric pressure, the transit time of a carrier the whole distance of 3000 feet was 95 seconds from the station to the Exchange, whilst it only occupied 70 seconds in returning. The pressures now employed are, in the one reservoir, 7 inches of mercury over, and in the other 6 inches under atmospheric pressure. With this arrangement the transit times were, from station to Exchange 1 min. 30 sec.; and from Exchange to station 1 min. 20 sec.

In the system in use in Paris the same apparatus constitutes both the receptor and transmitter for the carriers. It consists of a cast-iron stand or pedestal, surmounted by an air-tight box, in front of which is a lid or door. Two tubes enter this box from opposite sides; one leading to the pressure reservoirs and communicating through a cock or valve with a branch below it with the box, whilst the other branch from the box is connected with a tube open to the air at the top, and also provided with a cock. A central vertical tube closed at the top is used when carriers arrive, and acts then as an air buffer, against which they expand their force. Beneath the box another tube leads to the next station. In sending a message it is placed in a box and the door shut, the cock communicating with the compression reservoirs is then opened, and the pressure of air blows the carrier through the tube. At this time the cock communicating with the open tube is kept closed, but when a message is to be received this cock is opened and the other kept closed—the open tube admitting the escape of the air in front of the carrier.

According to Mr. Siemens's new method, a complete circuit is formed by the current of transmission, with which several stations may be brought into communication with each other. The transmitting and receiving apparatus is extremely simple, and consists of two short pieces of tubing the same diameter as the main tube, and out of the latter a piece is removed of equal length. By means of a crank, or rocking shaft movement, either of these short tube pieces may be connected with the main tube by a simple movement of a lever, and thus brought into circuit. One of these short tubes is open throughout. This is the transmitter. It is ordinarily kept in circuit, so that messages to other stations beyond may pass through. When it is desired to send a message the circuit is broken by moving the transmitter a little to one side; the carrier with its message is then placed inside, and after communicating by signal with the station for which it is intended, the transmitting tube is once more

brought into circuit, when the current of air immediately catches the carrier and hurries it on to its destination. Upon receipt of the signal at the further station for which the message is intended, the person in charge brings the receiver into circuit. This consists of a tube similar to the transmitter, with the exception that it is partially closed at one end so as to catch the carrier as it arrives. Its arrival is ascertained by the click caused by its striking the partially closed end of the receiver, which is then drawn back to extract the carrier, and the open transmitter is at the same time thrown into circuit so as to allow any through messages to pass. As each through message passes a station it causes a small bell to ring, as a signal to the superintendent, and to enable him to count when any message is due for his station. By this means a continual service of messages may be carried on in any circuit, the amount of business transacted being limited only by the means of the superintendents at each station to keep pace with the arrival and dispatch of messages.

AN ESSAY TOWARDS ESTABLISHING A "SCIENCE OF MONEY."

By A LONDON MERCHANT.

WHILE engaged with some views on the origin, nature, and use of money a few years ago, I happened to read Professor Müller's new work on the Science of Language; and from certain similarities apparent in the two cases, it then occurred to me, after his example, to entitle my subject the Science of Money. The Professor had satisfactorily established that language was not born of antecedent design, but rather of men's needs and capacities, in contact with external objects and events. As he had felt hesitation at the novelty of his term, much more had I at the unwonted apparition of a Science of Money. I did not therefore venture on the term on that occasion. Seeing, however, that the Science of Language is already a familiar phrase to us, I am encouraged to do so now. But I am still content with the introductory form of my title, hoping that on the next occasion with the subject I may at length venture to call it simply the Science of Money.

"As civilisation advanced," says Professor Price in his late lecture on Money, "an effective contrivance was

invented in coin, which every one consented voluntarily to take in exchange for the goods he had to sell, because he knew that when he himself required to buy he would be able to get other property of the same value as that he had sold for coin." If this be an accurate or probable account of the origin of our subject, there can be no Science of Money. Our chief question then is: Did money come into existence by antecedent design or otherwise?

To aid our illustration, let us take a few early historical data on the subject. They will present money to us in a simpler condition than at present, and in a state that may help us in tracing it still nearer its source. In early Greece iron was used as money; in early Rome rings of copper. Silver money came subsequently to Greece in her trading with Asia, along with the weights and measures and other commercial facilities of the teeming and busy East. Gold money came generally at a later time. The Greek trading communities—Argos, Ægina, Athens—readily adopted the silver; the interior and non-trading, as Sparta, clung longer to the iron. Lastly, the Lybians were reputed to have invented money—a question that will be estimated further on.

This rude money of early Europe, then, has developed into the vast and highly artistic money system of after times, concurrently with the great commerce of these times. But this advance has not been uniform over the world; and that world still presents to us even to-day, among Australian tribes, for instance, as well as other populations, a primitivism as free from industry in the commercial sense, from exchange of products and from money, as any that preceded Greece or Rome. We have ascended a step when, quitting our modern Australian, we come to Mr. Brookes's paterfamilias of Borneo, who, gathering a load of bees'-wax, perambulates the country till he has exchanged it for other things his household needs. But our Bornean showed readiness to advance when our countrymen, and others from without, introduced him to larger trading and the use of money. Commerce and civilisation seem born of such mutual intercourse. The steps of human progress are generally taken with a difference due to places and circumstances, and by intercourse these differences are mutually appropriated towards further progress. Civilisation, therefore, with its indispensable commerce, has chiefly flourished along the world's great streams of human intercourse, shaped, as these are perhaps chiefly, by physical and climatic features. The peoples who have remained outside, shunted from the active life of the world, have more or less preserved to us